Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

Air Transportation Safety Investigation Report A17O0243

HARD LANDING

Jazz Aviation LP
Bombardier DHC-8-402, C-GYJZ
Toronto/Billy Bishop Toronto City Airport, Ontario
09 November 2017

About the investigation

The Transportation Safety Board of Canada (TSB) conducted a limited-scope, fact-gathering investigation into this occurrence to advance transportation safety through greater awareness of potential safety issues. It is not the function of the Board to assign fault or determine civil or criminal liability.

History of the flight

On 09 November 2017, the Jazz Aviation LP (Jazz) Bombardier DHC-8-402 aircraft (registration C-GYJZ, serial number 4524) was conducting a scheduled flight, operating as JZA7977, from Montréal/Pierre Elliott Trudeau International Airport (CYUL), Quebec, to Toronto/Billy Bishop Toronto City Airport (CYTZ), Ontario, with 2 flight crew members, 2 cabin crew members, and 52 passengers on board.

At about 2050,[1] while on approach to Runway 26, the aircraft experienced mechanical turbulence.[2] As a result, the airspeed fluctuated rapidly during the approach.

Jazz standard operating procedures (SOPs) for stable approaches allow for a deviation of −5 to +10 knots from the planned approach speed once the aircraft is below 500 feet above ground level (AGL) on approach. However, the speed of the occurrence aircraft's approach varied from 119 to 141 knots. Because the speed deviations resulted from momentary wind gusts, the flight crew considered the approach to be stable.

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[1] All times are Eastern Standard Time (Coordinated Universal Time minus 5 hours).

[2] At the time of the landing, the winds were 300° magnetic at 24 knots, gusting to 35 knots.

Once the aircraft was below 100 feet AGL on approach, the following happened in rapid succession:

- The aircraft encountered momentary performance-degrading wind shear as a result of a wind gust, causing its airspeed to decrease. [3]
- The pilot flying advanced the power levers.[4]
- The aircraft touched down.[5]

Almost immediately after touchdown, the following happened in rapid succession:

- The main landing gear began to compress.
- The engine torque, in response to the power lever advancement, increased to a maximum of 42.5% and 40% on the left and right engines, respectively.
- The aircraft encountered a performance-enhancing wind shear, which caused the airspeed to increase.
- The power levers were retarded through the flight idle gate position to the propeller discing detent position.
- The momentary increase in torque and airspeed caused the aircraft to become airborne again, up to 4.5 feet above the runway, for about 2.75 seconds.

While the aircraft was airborne, after the first touchdown, the following happened in rapid succession:

- The propeller blade angles moved through the ground-idle range into the disc position,[6] which caused a significant loss of lift.
- The performance-enhancing wind shear decreased, and the combined reduction in lift resulted in the aircraft firmly contacting the runway.
- The flight data recorder (FDR) caution annunciator on the cockpit caution and warning panel illuminated ("FLT DATA RECORDER").

At this point, the FDR and cockpit voice recorder (CVR) stopped recording. The aircraft landed after bouncing, although this landing was not recorded on the FDR. The flight crew taxied the airplane to the gate without further incident. No anomalies or injuries were noted.

The aircraft was scheduled to depart for the return flight to CYUL at 2115, which was the crew's final flight for the day. The flight crew were aware that CYTZ's noise abatement curfew prevents departures after 2200.

The flight crew were concerned that the landing may have been a hard landing, although the overhead bins remained closed and neither pilot considered the landing to have been firmer than others previously experienced. As a precaution, the flight crew contacted Jazz's maintenance control centre (MCC) to enquire about the FDR caution annunciator illuminating during touchdown and to discuss the landing events.

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[3] Performance-degrading wind shear is a sudden change in wind speed or direction (e.g., a sudden decrease of the headwind component, or a change from a headwind to a tailwind) that has a negative effect on aircraft performance.

[4] The left power lever angle peaked at 62°, and the right power lever angle peaked at 63°.

[5] Initial touchdown was determined based on the minimum radio altimeter reading, the increase in vertical acceleration and the increase in pitch attitude. The flight data recorder did not record a weight-on-wheels indication.

[6] Disc position refers to the propeller in flat pitch, approximately 0°.

The MCC indicated that the illumination of the FDR caution annunciator was likely not related to the landing, and referred to the aircraft maintenance manual (AMM) for guidance on a hard landing.

The MCC also indicated that, if the flight crew determined that they had experienced a hard landing, a maintenance inspection would be required. The MCC stated that no maintenance personnel were currently available at CYTZ but personnel could be brought in from the company's hub at Toronto/Lester B. Pearson International Airport (CYYZ), Ontario. The time necessary to relocate the personnel and for the maintenance inspection to be carried out would exceed the airport's curfew, and the return flight would therefore have to be cancelled.

The flight crew were uncertain as to whether the landing had been hard enough to warrant such action, and, with no specific parameters available for making the determination, they decided to visually examine the aircraft by performing a walkaround. The flight crew did not observe any discrepancies during the walkaround and subsequently decided to conduct the return flight to CYUL.

While preparing to depart, the flight crew noted that the FDR caution annunciator was still illuminated. They contacted the MCC to further discuss the FDR caution annunciator situation and were again told that the annunciator illumination was not likely related to the landing event.

The flight crew, in coordination with the MCC, reviewed the procedures for an illuminated FDR caution annunciator. In addition to confirming switch selections, the flight crew performed the circuit breaker reset procedure. However, the annunciator remained illuminated.

It was determined that, in accordance with Jazz's Transport Canada–approved Q400[7] minimum equipment list (MEL), the aircraft could be dispatched with the FDR inoperative, provided that the CVR was operative and repairs were made within 3 flight days. Although the CVR had been tested on the first flight of the day, neither the flight crew nor the MCC considered reconfirming that the CVR was operative at this time.

After these discussions with the MCC, the flight crew considered the aircraft to be airworthy and decided to continue with the planned departure. Once the aircraft was airborne, the flight crew recorded in the aircraft journey log book that the FDR caution annunciator had illuminated and that the MCC had deferred the item in accordance with the MEL.[8] The flight crew also reported in the journey log book that they suspected a hard landing had occurred at CYTZ and suggested that maintenance perform a follow-up inspection at CYUL.

No abnormalities were noted during the takeoff, landing, or taxiing of the return flight to CYUL. Jazz maintenance personnel subsequently conducted an inspection of the aircraft at CYUL and found that the FDR system's inertia switch had activated and that there was physical evidence of a hard landing.

Aircraft damage

The inspection at CYUL found that the aircraft had sustained substantial damage, including buckling of the skin below the windows on the right fuselage (Figure 1). The landing conditions experienced by the right main landing gear during the second touchdown exceeded its ultimate design criteria, which resulted in failure of the orifice support tube during the in-stroke (Figure 2). Once the orifice support tube failed, shock strut damping was effectively lost, thereby generating significant bottoming loads.

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[7] Bombardier DHC-8-400 series aircraft are also known as Q400.

[8] The MCC provides the flight crew with a reference number for items deferred under the MEL.

Figure 1. Maintenance marks on the right-side fuselage showing areas of buckling

Figure 2. Orifice support tube

The calculated theoretical vertical load that would have been instantaneously generated when the landing gear bottomed out was at least 5.7*g*, which exceeded the design criteria for the landing gear.

Flight crew assessment of hard landing

Neither the aircraft manufacturer nor Jazz provide the flight crew with a definition of a hard landing or criteria to determine what a hard landing is. Pilots are expected to rely on their personal experience to make such a determination. In some cases, operational pressures may influence this assessment.

Maintenance assessment of hard landing

The AMM provides several definitions of a hard landing, stating that a hard landing has occurred if the "flight crew members report [one] in the aircraft Journey Log Book,"[9] or if the "aircraft makes a landing with a Vertical Acceleration in excess of the Vertical Acceleration (Nz) Threshold."[10] There is no way for the flight crew to determine the actual vertical acceleration on landing, and maintenance

[9] Bombardier Aerospace, Aircraft Maintenance Manual: Dash 8-Q400, "Hard landing – Inspection/check," Task 05-50-06: Inspecting After a Hard Landing (05 March 2017), p. 601.

[10] Ibid.

personnel can determine that a landing has exceeded the vertical acceleration threshold only after downloading and reviewing the FDR data.

Jazz has quick access recorders (QARs) on a number of Q400 aircraft; however, the occurrence aircraft was not equipped with one, nor was one required by regulation. A QAR is not typically designed to survive an accident, but when it does remain intact, valuable information beyond what was recorded by the FDR can be obtained.

Flight recorders

The occurrence aircraft's electrical system includes an inertia switch to provide an automatic means of stopping both the FDR and the CVR simultaneously, which prevents the erasure feature from functioning after a crash impact.[11] The double-pole inertia switch is placed in series with the power supplies of the FDR and the CVR. When subjected to a force of 5.5*g* along its sensitive axis, the switch opens, which interrupts the electrical path to each recorder, thereby stopping both recorders simultaneously.

When the inertia switch activated during the occurrence aircraft's landing at CYTZ, it caused the FDR and CVR to stop simultaneously. Therefore, neither the FDR nor the CVR was in operation during the return flight to CYUL.

Inertia switch guidance

The aeroplane operating manual (AOM) states, in section 6.4.9, "An inertia switch removes power from the system if the G forces are more than the preset limits."[12] Section 6.4.10 of the AOM contains the exact same sentence.[13] However, neither section indicates whether there are 2 separate switches or a single switch.

The AMM provides maintenance personnel with various explanations as to what causes the inertia switch to open (the AMM uses the term "impact switch"). The Jazz Q400 maintenance familiarization training indicates that the switch opens as a consequence of a high-impact landing.

Bombardier has produced a block diagram showing the electrical interface between the inertia switch and both the FDR and CVR. This diagram is not included in the AMM, nor is it available to operators.

The TSB tested the occurrence aircraft's inertia switch, and it was found to operate in accordance with the manufacturer's specifications. Additionally, it was determined that 10 to 20 milliseconds elapse from the moment the sensitivity threshold is exceeded to the moment power is interrupted.

Flight data recorder caution annunciator

The FDR caution annunciator illuminates steady amber when there is a defect in the FDR system or when the FDR is not electrically powered. The annunciator is not illuminated during normal operation.

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[11] This is in accordance with U.S. Federal Aviation Regulation 25.1459(a)(5) and the U.S. Federal Aviation Administration's requirement for a dedicated switch for both the FDR and the CVR. Bombardier Aerospace began incorporating an additional inertia switch in April 2010. This modification was not incorporated into the occurrence aircraft, nor was it required to be.

[12] Bombardier Aerospace, Aeroplane Operating Manual: DASH 8-Q400, Volume 3, Rev. 11 (04 July 2014), Chapter 6: Airplane Systems, section 6.4.9, "Cockpit Voice Recorder."

[13] Ibid., section 6.4.10, "Flight Data Recorder."

The AOM does not specifically state that the FDR caution annunciator illuminates when the inertia switch is activated.

Although the AMM states that when the switch is activated it removes power to the FDR and CVR, it does not specifically state that the FDR caution annunciator illuminates under this condition.

At Jazz, the illumination of the FDR caution annunciator was typically rectified either by performing a circuit breaker reset procedure or by replacing the defective FDR.

Cockpit voice recorder

The flight crew must conduct a CVR test on the aircraft's first flight of the day. There is no requirement for the flight crew to test the CVR again during subsequent flights that day.[14] The PASS/FAIL light on the CVR cockpit control unit provides a visual indication of the results of the test. The PASS/FAIL light is not illuminated during normal operation.

There is no caution or warning annunciator to indicate when the CVR is not functioning. Performing the test is the only way that a flight crew can know that the CVR is not being electrically powered; in such a case, the PASS/FAIL light does not illuminate when the test is initiated.

During the inspection by maintenance personnel at CYUL, the inertia switch was reset, which caused the CVR to be electrically powered and the data for the occurrence flight and landing to be overwritten.

Journey log requirements

Section 605.94 of the *Canadian Aviation Regulations*[15] requires that the "particulars of any defect in any part of the aircraft or its equipment that becomes apparent during flight operations"[16] be entered into the aircraft journey log book "[a]s soon as practicable after the defect is discovered but, at the latest, before the next flight."[17]

Safety action taken

The actions that Jazz took to prevent a similar occurrence included

- providing additional training on how to recognize hard landings,
- strengthening and clarifying procedures and guidance associated with suspected or actual hard landings,
- adding a warning within flight crew guidance to inform crews of the risk of a hard landing if a landing is continued following a bounce with the power levers at flight idle or disc, and
- conducting a review of flight data analysis practices and effectiveness as they relate to preventing a departure when the aircraft's airworthiness is concerned.

This concludes the TSB's limited-scope investigation into this occurrence. The Board authorized the release of this investigation report on 04 July 2018. It was officially released on 09 July 2018.

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[14] Jazz Aviation LP, *Aircraft Operating Manual*, DH4 Q400 AOM Volume 2, Revision 11 (15 January 2017), Section 2: Normal Procedures, section 2.1.3, "Flight Compartment Check," p. 2.1-8.

[15] Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, section. 605.94.

[16] Ibid., Subpart 605, Division IV, Schedule I, item 9.

[17] Ibid.

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Air transportation safety investigation report A17O0243

Cat. No. TU3-10/17-0243E-PDF
ISBN 978-0-660-27090-6

This report is available on the website of the Transportation Safety Board of Canada at www.tsb.gc.ca

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